Repair of electronic equipment: tools, techniques and tips

By **Jean-Francois**

(This article (240069-02) is published in Elektor May/June 2024.)

Do you want to save money while extending the life of your electronic devices? Repair using your own tools and devices! From mastering basic tools to explaining common problems, this practical guide to repairing electronic devices will boost your self-confidence when you repair your equipment.

Let's first take a look at the tools that are useful for most electronic repairs. Of course, everyone has their own list of favorite tools, depending on personal preference. Here is my list. If you are a beginner, you might have a few ideas. If you only have one or two of these tools and the list seems too long or far too expensive for you, don't panic! On the one hand, you can always do without something until you have decided that it is time to buy a new tool, and on the other hand, you can find most of these things either very cheap from China or at affordable prices in the used market anywhere.

Let's start with the most important tools (**Figure 1**). You need at least one of each: a multimeter, a soldering iron and solder, an oscilloscope, and an adjustable power supply. To check solder joints and examine the board for defects, a small magnifying glass with a sufficiently high magnification (in my case 10x) is a great help. Even a very inexpensive magnifying glass is infinitely better than no magnifying glass; I personally use a $5 plastic model from RS (No. 136-8106), which serves me well.

Figure 1. Useful tools.

You could argue, but in my opinion a second multimeter and a second soldering iron are also indispensable tools. Two multimeters used at the same time is useful, maybe for testing power supplies by monitoring the output voltage while increasing the output current. The second soldering iron is almost irreplaceable as a supplement to the first soldering iron, since you can then solder all types of SMDs with a soldering iron in each hand.

Speaking of soldering, here are a few additional aids. Desoldering braid (I recommend the tinned variant) and flux paste. Cotton swabs and 99% (or if necessary 90%) isopropyl alcohol are suitable for cleaning boards after soldering. I recommend filling the alcohol into small plastic bottles (2 or 5oz.) so you can apply small amounts, and also use one of these bottles for a 50/50% isopropyl acetone mixture - very effective for hard-to-remove residues. If you can afford it, a professional cleaner such as Fluxclene or Contact LR is of course good, but not absolutely necessary. To remove strong corrosion caused by the penetration of water or the emission of electrolyte from a capacitor, a fiberoptic pen is very useful.

Optional tools as rescuers

Optionally = you can do without these tools, but once you bought them, they will prove to be very useful. I recommend a low-cost de-soldering station. With it, transistors, capacitors, DIP ICs, connectors, relays and so on can be quickly and cleanly desoldered, so it would be a pity to make do too long without them, especially with such cheap products as the ZD-915 or ZD-8915 models for under $100. I would add to this category an ESR or LCR meter and a very inexpensive component tester such as the LCR-T4 model.

A light bulb as a current limiter

[Beware of high voltages nearby]

With regard to small, self-made tools that are gathered over a lifetime, I would also mention a light bulb as a current limiter. This is particularly useful in the repair of power supplies, especially with errors such as short-circuited diode bridges or transistors in the primary circuit or a blown fuse. After the repair, it is a good idea to limit the maximum current if something has yet to be found to prevent the same components from burning up again.

The principle is very simple: switch an incandescent lamp with a corresponding nominal voltage in series with one of the two power supply lines. In the event of a problem (at worst, a short circuit between the phase and the neutral conductors) there are no more explosions; the lamp simply lights up and gives you time to disconnect without damage.

You should have several lamps with different wattages to limit the current to a higher or lower value, depending on the device to be tested. This is easy with a few spare light bulbs and a light bulb holder; you simply screw the light bulb of your choice as needed. Even if in many countries classic filament lamps have disappeared from the store shelves, they are readily available on the Internet. Of course, energy-saving lamps or LEDs are not suitable for this task.

For my part, I made a somewhat more complicated structure than necessary (**picture** 2), by switching several small halogen bulbs in parallel with a rotary switch (20 W / 230 V, G9), so that I can limit the current in five stages from 80 mA to about 400 mA.

Now let’s talk about repair methods. Here are a few things you might find helpful.

Figure 2. A self-built current limiter.

How to perform electronic repairs

First, take stock of the situation. Do you know exactly where the fault lies? If it's a device that you heard of or that you used yourself when the bug occurred, you probably have a pretty good idea of the problem. But take the time to record everything that could be a clue. Does the device have a display that shows an error message? Does it run from a cold state and stop after warming up? Or the other way around? Has the device suffered a mechanical blow? Does a slight mechanical tap affect the operation of the device? All these clues will help you troubleshooting, so don't overlook them. If possible, try to observe the error personally if it is a repair that you are doing for someone else.

Look up on the Internet if in any forum someone had the same problem with the same device. See if a maintenance manual or schematics are available.

The next step is the disassembly. Remember to take photos to facilitate reassembly, and number/label the plugs on the cables with a fine marker if necessary, so that you can clearly reattach them correctly during reassembly.

First the visual inspection

Start with a thorough visual inspection when diagnosing: I don’t know how often I have seen problems this way, if not the exact error, after examining all parts of the board: blown components, signs of overheating, missing components (sometimes the connections of components break off in motion or after they were stressed by temperature fluctuations), cracked solder joints and tracks, and so on. Use your other senses: is there a suspicious smell? A strange noise when you shake the case?

Try to identify and locate functional units. Power supplies, boards behind front panels, digital control panels, analog circuits, output stages if present, etc. Draw a conclusion about possible sources of error.

Choose a way to proceed: either the direction of flow (energy flow or information flow) or against the flow. From the inputs to the outputs or the other way around. There are no fixed rules; at the beginning you can choose arbitrarily and switch between the two techniques as the diagnosis progresses. With one power supply, which power indicator lamp does not light? It often makes sense to start with the line/mains input and check sequentially down to power chain: fuse OK, diode bridge OK, power correction transistor OK and so on. If the power supply can be switched on, but only one of the many outputs has an error, it makes more sense to start at the output and work backwards.

Is the power switched on?

First check the PCB tracks. Sometimes there are test points, or you can measure the voltage at the electrolytic capacitors. Common voltages are 12V, 5V, 3.3V and corresponding negative voltages to ground. A fluctuating or missing voltage indicates a possible error.

If the power supplies appear to work, check whether the function blocks you encounter are also powered by the measured voltages at the IC’s and microcontroller’s power supply connections. Using data sheets and experience, you can determine which pins you need to observe. If the voltage is zero, check with an ohmmeter if the rail is short-circuited to ground. If this is the case, look for the short circuit; if this is not the case, keep looking to find out why the power supply is not there.

Whenever possible, I try to solder as few components as needed. Nevertheless, it happens that, when in doubt, a component may have to be desoldered in order to confirm a measurement, especially when searching for short circuits. But beware! I have often come across boards wrongly assembled, and it can happen to anyone that you

accidentally solder an SO-8 or SO-14 IC, which leads to anger and frustration during the next test. Take a look at the photos you've previously taken!

In this phase of troubleshooting, you probably need to alternate between testing components in-circuit (without power), resoldering, resoldering, replacing components, testing with the power switched on, and so on. Take time and keep a clear head. And above all: Never solder on a powered-up circuit! Make sure that this does not happen accidentally. Apart from the security aspect, there is a risk that you are shorting with the soldering iron shortened and causing damage.

Safe measurements

Never perform oscilloscope measurements on the primary side (line/mains side, before the transformer) of a power supply unless you are fully informed and have a certain experience with differential probes and isolation transformers. There are fewer security risks on the secondary side, but still the risk of causing faults. Instead of taking the risk of slipping with the probe tip, I often prefer to solder a small piece of wire to the relevant node and touch the probe to it. Another possibility is to use of high quality, thin mini-clips, such as those of EZ-Hook (see **picture 3**). So I have my hands free to operate the on/off switch and control elements of the oscilloscope.

Figure 3. Safe testing of circuits under voltage.

When I was working in an electronics workshop, I constantly used my computer to search for data sheets and pinouts of the countless new components that I did not know when repairing a particular device. If you work without schematics (which are rarely available) and sometimes on boards without parts placement layouts, lists of SMD markings can be invaluable tools to help identify components.

Finally, comes the moment that you found a defective component. No doubt, your measurements are categorical and unambiguous: the part has blown up. Congratulations! Search around for further damage on all traces emanating from all pads of this component.

Replace components

Try to replace the component with an identical one by looking at the usual suppliers: RS, Mouser, Digikey, etc. If possible, avoid eBay and AliExpress, where the chance to get a counterfeit component is sometimes up to 100%.

If the component is difficult to procure or is no longer on the market, you have no choice but to find an equivalent one. Pay attention to the type of housing, pin assignment and the main features: maximum voltage and current of the transistors, switching speed and so on. If in doubt, do not hesitate to ask for help in a forum, where the members are generally very helpful and friendly.

In the following section, we will look at some common errors/problems that may occur with some of the most common components, and provide some tips for checking them.

Compatible components, common faults

It can be useful to have an idea of the error types that can occur with a certain type of component so that you can search efficiently. One often hears that electrolytic capacitors are the culprits. This sometimes applies to very inexpensive switching power supplies, built with capacitors limited to 85°C, rather than with slightly more expensive 105°C versions. Often the design is very poor both in terms of voltage and capacity, which overburdens the capacitors, so that they fail - usually shortly after the expiration of the legal guarantee.

However, this is by no means the rule for equipment that is better designed or for testing and measuring instruments and industrial equipment. Below you will find a list of frequent failures, listed by component type.

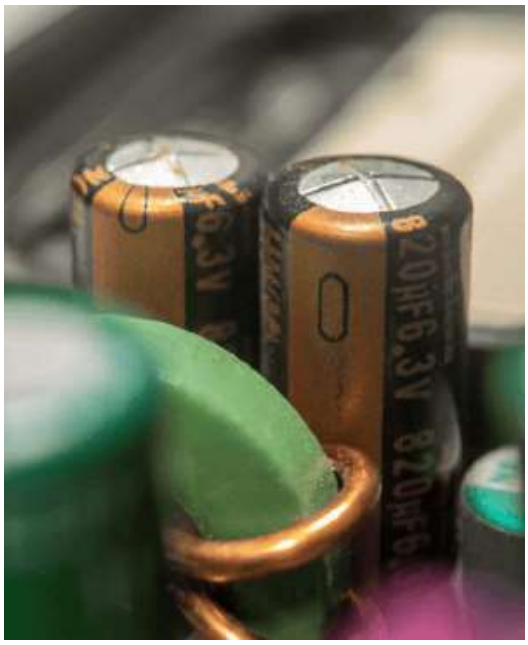


Figure 4. The infamous electrolytic capacitors with a bulbous cap. (Source: Wikipedia)

Electrolytic capacitors: Sometimes they bulge, as shown in Fig 4, or they have lost electrolyte, lose capacity, or have too high an ESR value. Test with a multimeter (in Capacitor mode), an ESR meter, or an LCR meter. Bulging or leaking capacitors must be replaced without further testing; with normal-looking capacitors, a terminal must be desoldered to prevent adjacent components from affecting the measurement.

Power transistors (bipolar or MOSFET): Often short-circuited, sometimes they no longer conduct. Check with multimeter in diode mode. Identify the pin assignment first. For a bipolar transistor, you check the basic emitter and basic collector connections. Also check whether there is a short circuit between the collector and the emitter. Check for a MOSFET whether the internal diode of the MOSFET is measurable between drain and source (blocking layer voltage 0.5 V or 0.6 V) and whether the gate is isolated from the other two pins (**Figure 5**).

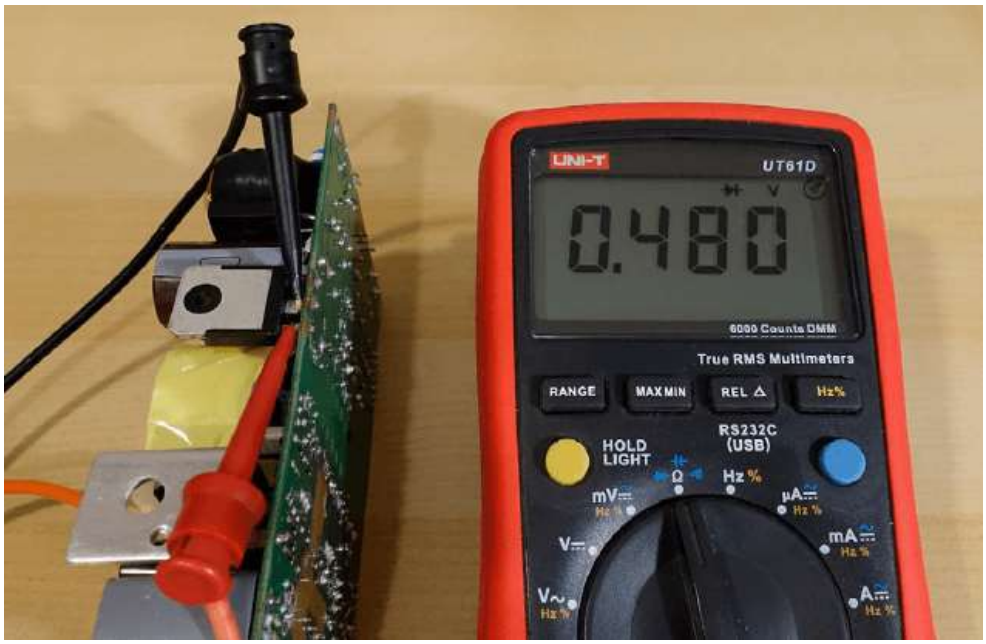


Figure 5. Testing of a power MOSFET using a DMM in diode mode.

Power diodes, rectifier diode bridges: Often short-circuited, they no longer lead more rarely. When testing in diode mode, you should notice a voltage of about 0.6 V or 0.7 V and in the black direction OL (overload, infinity) for conventional diodes in the passage direction. With Schottky diodes, the voltage is lower and is about 0.3 V.

Power resistors: Often open. Typical case: resistors used to limit the starting current of switching power supplies.

Wired or SMD diodes or Z diodes and small bipolar or MOSFET transistors: short-circuited or open. Test them in diode mode with the DMM.

Power ICs: are those that potentially restrict some heat, for example motor drivers: short circuit of the supply pins against ground or short circuit of the output pins against ground or operating voltage. This is often the case with switching regulator ICs on the primary side of switching power supplies. Especially those who contain the control logic and the power transistor in the same housing (such as the VIPER20 from ST and others) are sensitive.

Plastic film capacitors: loss of capacity. Less rare: short circuit. Capacity losses are common, especially when these capacitors are used as capacitive dividers, i.e. to obtain a voltage of some volts to supply a logic circuit from the mains voltage. In this case, an alternating current flows through the capacitor, so that it ages prematurely.

Transformers: Open circuit (blown) or short circuit between the spirals or windings (leads to overcurrent and overheating).

Wired or SMD resistors: Sometimes they are visibly blown, sometimes they result in an open circuit, which is not visible to the naked eye. This can be easily checked with an ohmmeter: Due to the different components connected in parallel to the resistance to be tested, the measured resistor must always be equal to or lower than the value specified on the resistivity marked. If this is not the case, the resistance has blown or strongly highly impeded.

SMD ceramic capacitors: Sometimes short-circuited. In this case, the entire supply rail is short-circuited with the mass. To locate the short circuit on the board, you can use a laboratory power supply. Set the voltage to a low value of 1 V or 2 V and the maximum current to about 1 A.

Connect it to the track and pay attention to the polarity. This forces electricity into the short circuit. Then use the digital multimeter in millivoltmeter mode to continue to approach the short circuit. The voltage is lowest above the short-circuited capacitor. Some people recommend using a more powerful power supply and adjust the power to a higher value. This allows the short-circuiting component to be heated, which is then visible with a thermal imaging

camera. If you use this technique, be careful, a higher current could also burn some traces. In very rare cases, these capacitors can also interrupt the circuit - see the **text box** about the power supply that did not want to cooperate.

Relays: Your contacts can become high-impedance after a large number of operations. This can be checked with the ohm meter at the contacts by supplying the relay coil with the corresponding voltage from a laboratory power supply. Pay attention to the right voltage for the coil and the proper polarity to avoid damage to the rest of the circuit. The positive terminal can usually be determined by looking at which of the two coil connections is connected to the cathode of the freewheel diode, which is often nearby. If in doubt, you should solder the relay to test it outside the circuit.

Pressure buttons: Sometimes short-circuited (which leads to irregular operation of the device), sometimes no longer contact (the device no longer reacts), especially when they have come into contact with water.

Soldering compounds: Some lead-free alloys tend to crack with age, as a result of repeated temperature changes. These can be difficult to see with the naked eye, but a hair-fine crack can be enough to completely interrupt the connection. This shows how important it is to examine the entire circuit board with a magnifying glass. An example of pretty big cracks can be seen in Other, much thinner cracks are much more difficult to find.

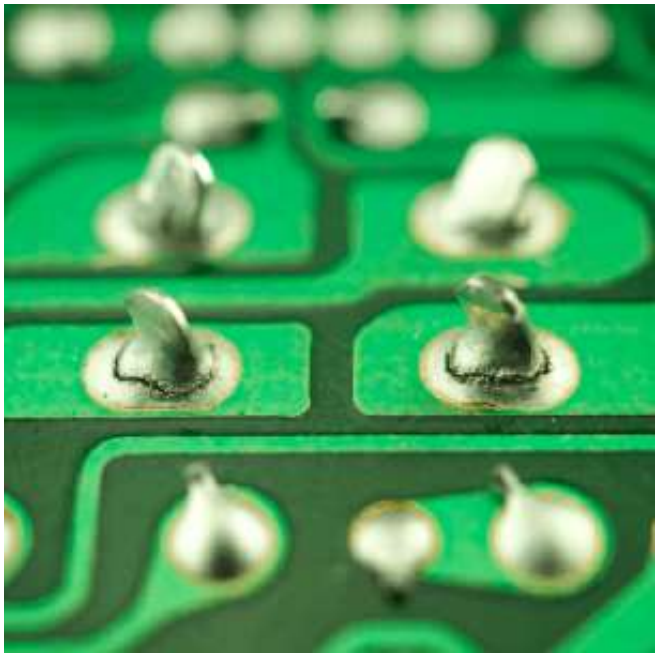


Figure 6. These solder joints have seen better days.

Quartz: They are generally reliable, but can stop swinging after a mechanical shock. If the microcontroller to which a quartz is connected is active and some LEDs are blinking or some displayed on the LCD display, you know that the quartz is working. If no such activity is to be recognized, it is easiest to scan one of the connections with an oscilloscope, and against ground. Then move the probe to the second port. You should notice a stable oscillation with an amplitude of at least several hundred millivolts at the frequency indicated on the quartz. One of the signals will have a greater amplitude than the other - that's normal.

Note: In order not to disturb the oscillation too much, a 10 probe should be used. Sometimes the input capacity of the oscilloscope probe stops the oscillation of a quartz, although the quartz is fine. In this case, try again at the second connection: This time you should see an oscillation. Oscillators often have an input side with a high impedance on which this can happen. The output side with its lower impedance is less easy to disturb. If you do not see anything on any of the connectors, either the microcontroller is not switched on or the quartz is defective.

Other errors: In a repair shop for industrial electronics, we encounter errors that are a little different from those that occur with consumer electronics. For example, liquid damage caused by the penetration of water when washing machines is very common. Since the devices work at high voltages (400 V) and are equipped with circuit breakers for

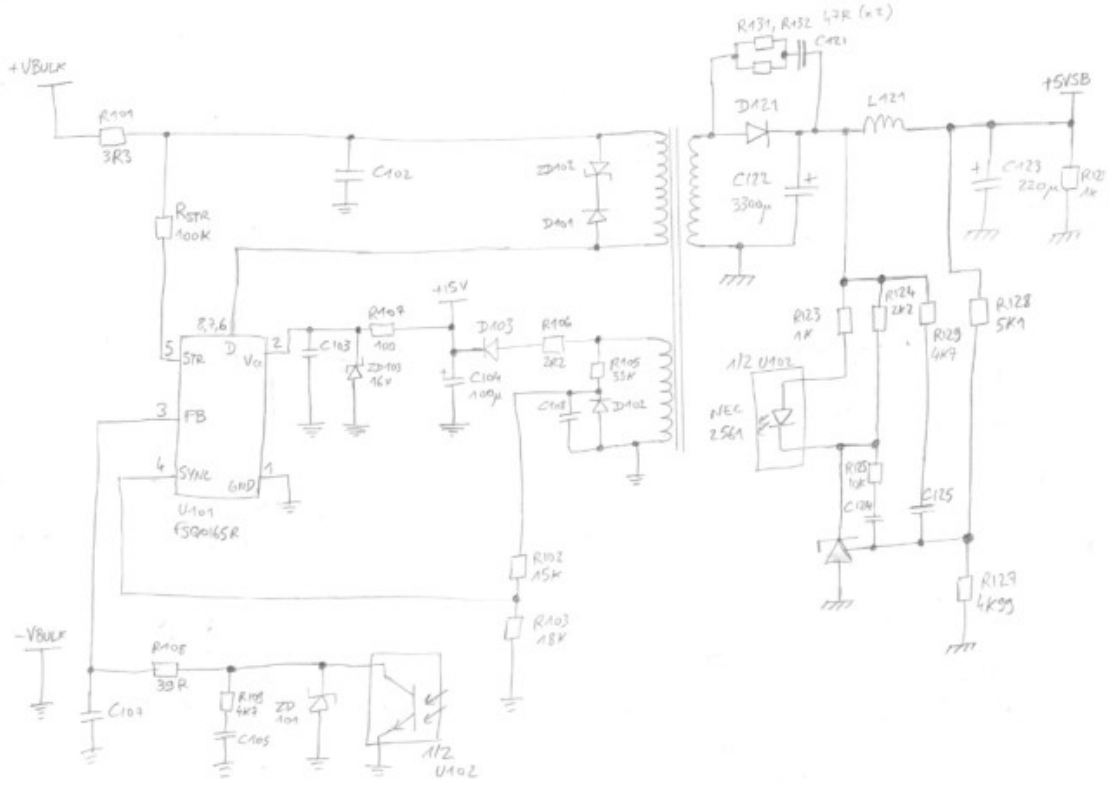
considerable currents, the damage can be serious. I often came across fire spots, evaporated conductors/wires/connectors, open NTC thermistors, short-circuited varistors and strong oxidation onto conductor paths, pads and components. After all, the connectors were also often oxidized or had bad contacts, since they had come loose due to vibrations. This often leads to arcs between neighbouring pins.

Beautiful views

Now you should be able to tackle repairs with more confidence and serenity. I would like to encourage you to try it - the results and satisfaction that you will draw from it are worth the effort. Also don't hesitate to look around in the forums and on YouTube, where you will find some very interesting content. Each of the electronics specialists on YouTube has their own personality and of their own, often different methods - that makes it so rich. For example, when it comes to repairing testing and measuring instruments, some videos of The Signal Path or FeedbackLoop are inspiring; when it comes to switching power supplies, DiodeGoneWild produces videos full of information; and finally, for retro computer enthusiasts, watch the videos of Tony359. Good luck with your repairs and have fun!

A power supply that did not want to cooperate

gave me a lot of headaches. I examined a faulty ATX power supply, a CX400 from Corsair from the 2010s. It switched off after some time. The first problem was that the power supply switched on the PC, but categorically refused to start on my workbench when I used the classic technology to short-close the green PS-ON wire against ground, which made my diagnosis more difficult. Since I was not experienced at the time, I did not immediately come up with the idea of selling an additional ohmic load to the 5 V-SB rail (standby supply) to fix this problem.



After I had done this, I noticed a considerable instability of the 5V-SB voltage, with a sawtooth-like ripple of several volts in the amplitude. Nevertheless, all notoriously suspected electrolyte capacitors at this outcome (and also at the other outlets) were in good condition. In order to make it easier for me to find troubleshooting, I made a hand-marked section of the circuit diagram, as shown before. I strongly recommend that you do the same if you cannot get any progress. Wiring diagrams, even incomplete and hand-drawn, are always helpful.

In fact, there was the small C107 SMD ceramic capacitor, which was part of an RC low-pass filter, in the feedback loop of this rail. This capacitor was blown and nothing more filtered, but caused the instability. A very rare mistake! A few years later, I came across someone who had the same problem with the same component in the same power supply while browsing in a forum. It was probably a manufacturing defect that caused the capacitor to break through due to temperature fluctuations.

A few extra helps

- Use as sharp probe tips as possible to overcome the oxidation layer on solder joints and make reliable measurements on components without having to press too much. This reduces the risk of slipping. Cheap measuring tips for multimeters are often made of clad brass and quickly become blunt. I use PRUEF 2 from Hirschmann for my part. They are very sharp, and I regularly sharpen them on a small grindstone.
- If the component markings are difficult to read by a thick clear varnish, the so-called “conformal coating”, it can often be removed with acetone, so that the markings can be recognised better. Use cotton swabs and a hard wooden tool, for example, a chopstick to scratch. Do not use a metal tool, as this scratches the surface of the component and makes reading the marking additionally more difficult.
- Some switching power supplies require a minimum load to operate. A suitable power resistance is sufficient, but is not always to be found on the board itself. Think of the minimum load if the power supply you want to examine does not start or its output voltage is not properly regulated.
- Sometimes SMDs are glued with a point of red glue before soldering the wave to hold them when they stand on their heads. It is difficult to escape them without damaging the component and pads. Heat all connections simultaneously with a large solder tip and plenty of solder tin. For small components with two connections, a “knife tip” can be well suited to heat both sides simultaneously. For larger components, use two soldering irons. Carefully guide an X-ACTO blade under the component while heating to replace the glue.
- Beware of charged capacitors! In particular, charging capacitors on the primary side of switching power supplies are often charged to 325 V. Sometimes there is a special resistance to unload it when the network is switched off, but not always. Before each testing or measuring, check with a multimeter whether the capacitors are completely discharged and discharge them if necessary. I use a pair of multimeteron units that are connected to each other via a 2.7 k performance resistance (5 W), as seen on the adjacent photo. Do not do this with a screwdriver, as this, the solder joint and also the capacitor can be damaged by the sudden current peak.

Editor's note: This article (240069-02) is published in Elektor May/June 2024.